Exchange rates and its impact on crude oil market

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Abstract. This study examines the dynamic relationship between exchange rate fluctuations and crude oil returns using a vector autoregression (VAR) model and orthogonal impulse response functions. The study reveals that exchange rates have a significant impact on the returns of crude oil. Notably, AUD/USD and EUR/USD exchange rates show strong initial effects on WTI and Brent crude oil returns, respectively. The patterns suggest that exchange rates are a pivotal factor influencing oil prices, essential for investors and policymakers in oil-dependent economies. The findings highlight the necessity for robust economic strategies that account for the intricate link between exchange rates and crude oil markets.

Keywords: Brent, Exchange rates, orthogonal impulse responses, vector autoregression (VAR), WTI.

1. Introduction

The intricate relationship among oil, currency exchange rates, and commodity prices reveals numerous facets and dependencies. Oil prices significantly influence the global economic landscape, affecting currency exchange rates and commodity pricing. An uptick in oil prices raises both production and transportation costs, thereby influencing commodity prices. Moreover, rising oil prices can induce inflationary pressures, affecting currency exchange rate volatility. Conversely, exchange rate fluctuations might influence oil and commodity prices. An appreciating currency can reduce the cost of imported oil, while a depreciating currency can increase it. Changes in exchange rates can also affect the competitiveness of commodity exports, influencing their prices. The nexus between oil, currency rates, and commodity prices is intricate, where each element influences and is influenced by the others.

Exchange rate dynamics significantly affect commodity prices and can introduce heightened volatility in the commodities market. Currency exchange rate volatility directly influences commodity pricing. In international trade, when a country's currency depreciates, its exports often gain a global market advantage. This can lead to increased demand for those goods, pushing commodity prices upward. Investors might manage currency risks or capitalize on exchange rate shifts through commodities market participation, potentially boosting trade activity and liquidity. However, it's crucial to recognize that such actions can also influence price fluctuations. Price variations in commodities can destabilize the economy, impacting sectors like industries, businesses, and consumers. In contrast, stable commodity prices can foster certainty, enabling businesses to devise effective investment and production strategies.

Oil is an invaluable commodity pivotal to modern society. Renewable energy sources are vital, supporting industries like transportation, industrial processes, and power generation. The global economy heavily relies on oil due to its significant role in industrial progress and economic growth. As Mignon [1] (2015) argued, currencies of major oil-exporting nations are especially susceptible to short-term trading fluctuations, especially during commodities market volatility. The geopolitical significance of oil cannot be understated, as it often dictates international relations and influences global power distribution.

Oil is essential for meeting global energy demand, particularly in energy production. Its versatility and efficiency in transportation and storage have made it a preferred fuel for vehicles, airplanes, and ships. Petroleum is also fundamental to industries, aiding in the production of various goods like

polymers, chemicals, and lubricants. This widespread utility underscores its vital role in fostering economic growth and technological advancement.

From an economic perspective, the oil industry profoundly impacts the global market. Oil price volatility can influence inflation, trade balances, and overall economic stability. Countries exporting oil often heavily rely on oil sale revenues to fund various government programs and infrastructure development. Such reliance brings both opportunities and vulnerabilities, as they become exposed to market shifts and geopolitical tensions.

Geopolitically, oil has been a catalyst for global conflicts and power struggles. Countries with vast oil reserves can exert significant influence on international events, using their economic leverage in diplomatic negotiations. Oil reserve management and access can shape alliances, spark conflicts, and even influence war outcomes. Thus, understanding oil's geopolitical importance is essential given its potential to reshape global power dynamics.

The intricate interplay among national currencies forms a complex web of economic interactions. Each country has its unique currency, serving as a transaction medium and a value measure. However, these currencies' stability varies and can be influenced by factors like economic indicators, government policies, and market trends. Exchange rates, which determine a currency's value against another, play a pivotal role in international trade and investments. These rates depend on countries' monetary policies, which can be fixed or floating. Some nations peg their currency to a stronger, more globally recognized one, like the US dollar or euro. Such pegging can enhance stability and trust in the domestic monetary system but also means local economies are influenced by the stronger currency's monetary policy.

This study mainly employs econometric analysis to explore the dynamics between various currencies and crude oil. The goal is to derive meaningful insights. The VAR model is used to examine causation among multiple variables.

2. Literature review

There has been voluminous literature that considers the relationship between exchange rates of crude oil pricing dynamics. Yousefi and Wirjanto [2] (2004) conducted an empirical analysis of how OPEC member countries' crude oil prices react to changes in the US dollar exchange rate and the prices set by other members. The findings support the notion that there is no unified price setting by OPEC in the international crude oil market and emphasize a cross-regional aspect of crude oil price dynamics.

Ghosh [3] (2011) investigated the relationship between crude oil prices and the exchange rate in India during a period of high oil price volatility, using GARCH and EGARCH models. The study finds that increases in oil price returns lead to a depreciation of the Indian rupee against the US dollar and that oil price shocks have a lasting impact on exchange rate volatility, with both positive and negative shocks affecting the exchange rate similarly. Reboredo and Rivera-Castro[4] (2013) employed the wavelet multi-resolution analysis to explore the dependence between crude oi prices and US dollar exchange rates, identifying different relationship across timescales and particularly noting contagion and interdependence between these markets during the global financial crisis. It finds that pre-crisis, oil prices and exchange rates were weakly dependent, but post-crisis, there was evidence of contagion, negative dependence and lead-lag effects between the two. Hartley and Medlock[5] (2014) examined the relationship between crude oil and natural gas prices in the US, acknowledging the influence of the exchange rate on the relative pricing between the two. While confirming previous findings that technological changes affect the substitutability of oil and gas, the study also identifies the exchange rate as a factor that impacts their relative prices, along with weather, seasonal factor, inventory level and supply disruptions. Atem et al.[6] (2015) examined how exchange rates react asymmetrically to various types of shocks in the crude oil market, and found that demand shocks lead to a depreciation of exchange rates, with the degree of exchange rate response varying based on the size and nature (positive/negative) of the shock.

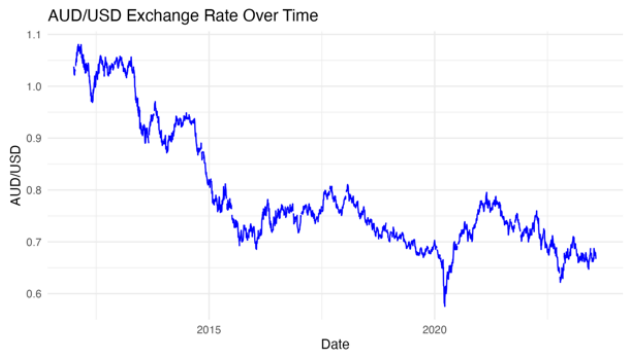
Jammazi et al.[7] (2015) employed a wavelet-based nonlinear autoregressive distributed lags model (W-NARDL) to explore the asymmetric effects of US dollar exchange rate fluctuations on crude oil prices, accounting for both short- and long-term nonlinearities. It discovers that the crude oil price is more significantly affected by long-term decreases in the value of the dollar than by the increase, highlighting the importance of denoising data to accurately access the interaction between oil prices and exchange rates. Bal and Rath[8] (2015) investigated the nonlinear causal relationship between crude oil prices and eschange rates in the context of China and India, using the Hiemstra and Jones nonlinear Granger causality test. The study finds significant bi-directional nonlinear Granger causality between the variables for both countries, with robustness checks indicating consistent results for India, but for China, it reveals a unidirectional causality from the exchange rate to oil prices, with a reverse effect from oil price to exchange rate. Other than US, China and India, Yunusa[9] (2020) analyzed the impact of exchange rates on Nigeria's crude oil exports to various trading partners. More recently, Sun et al.[10] (2022) examined the impact of the launch of China's crude oil futures on the relationship between the domestic crude oil price, the international crude prices, and China's exchange rates, and found that, post-launch, fluctuations in the USD/CNY exchange rate have a significant positive effect on China's crude oil prices.

Clearly, the literature on the relationship between exchange rates and crude oil pricing dynamics suggests that exchange rate fluctuations – particularly those of the US dollars – have significant effects on crude oil prices. Our study extends the literature by investigating the exchange rates of major currencies and their effects on crude oil pricing dynamics.

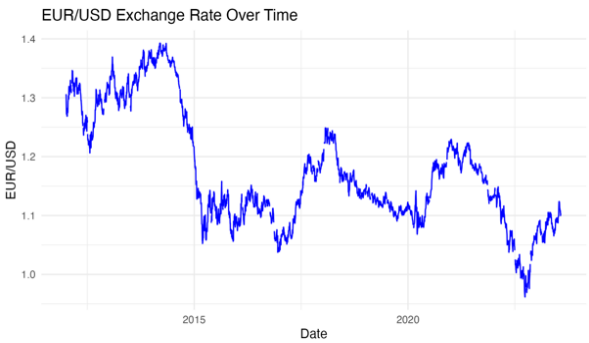
3. Data

Exchange rates can affect crude oil due to several reasons. First, crude oil prices are typically quoted in US dollars. When the value of the dollar strengthens against other currencies, it takes few dollars to buy the same amount of oil, and vice versa. Therefore, changes in the value of the dollar can directly impact oil prices. Second, a strong currency can make imported goods, including oil, cheaper for a country, and vice versa, thus affect demand, and in turn, oil prices. Third, currency fluctuation can influence investment and speculation. If investors/speculators believe a particular currency is expected to strengthen, they may invest more heavily in assets (such as oil) denominated in that currency, pushing up the prices. To study the effect of the exchanges rates on the oil prices, we chose the AUD/USD, EUR/USD, GBP/USD, USD/JPY exchange rates, and the West Texas Intermediate (WTI) and the Brent crude oil prices.

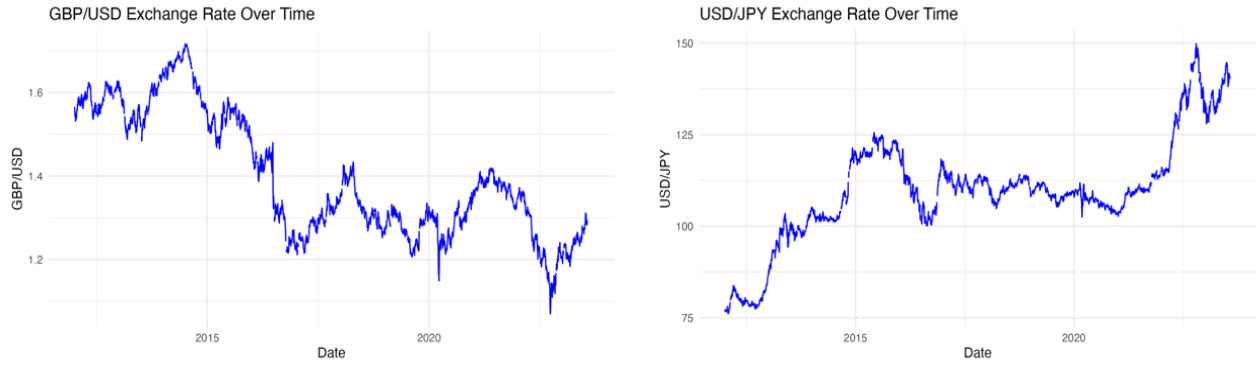
The determination of exchange rates is influenced by multiple factors including interest rates, inflation, economic indicators, and market expectations. Variations in these determinants can lead to shifts in the currency rate. The exchange rates of AUD/USD, EUR/USD, GBP/USD, and USD/JPY are visualized in Figure 1.



(a) AUD/USD.



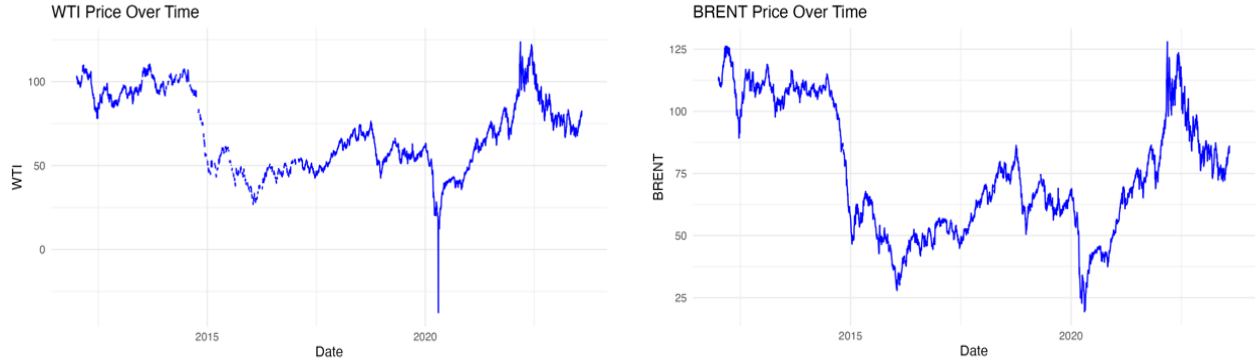
(b) EUR/USD



(c)GBP/USD. (d) USD/JPY.

Fig 1. Exchange rates.

The West Texas Intermediate (WTI) is widely recognized as a major benchmark for crude oil and holds significant importance in the global oil market. Brent Crude is another major global benchmark for oil purchases and tends to be drawn from oil fields in the North Sea. Often considered as the counterpart to WTI. The pricings for both WIT and Brent are influenced by a myriad of factors, encompassing geopolitical tensions, global supply-demand balances, OPEC decisions, and various other market dynamics. Their dynamics are visualized in Figure 2.



(a) WTI. (b) Brent.

Fig 2. Crude oil pricing dynamics.

4. Empirical analysis

4.1. Preliminary analysis

The visualizations from Figures 2 suggest that the crude oil prices may not be stationary, therefore, we work with the continuously compounded rates of return; to match the rates of return for the crude oil, and we also converted the exchange rates into continuously compounded rates of return. The descriptive statistics for these continuously compounded rates of return are summarized in Table 1. Clearly, the augmented Dickey-Fuller (ADF) tests are highly statistically significant, which rejects null hypothesis of a unit root, therefore favoring the stationarity of the rates of return. Note that the vector autoregression (VAR) model is used here, to analyze the comovements of variables.

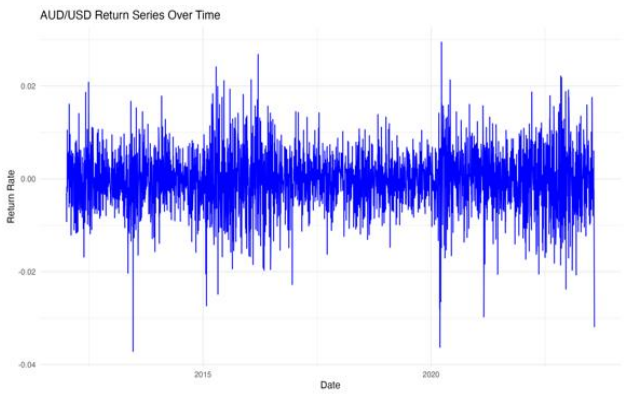
Table 1. Descriptive statistics of continuously compounded rates of return for various exchange rates and WTI and Brent crude oil.

	AUD/USD	EUR/USD	GBP/USD	JPY/USD	WTI	Brent
mean	-0.0002	0.0000	-0.0001	-0.0002	0.0002	-0.0001
variance	0.0000	0.0000	0.0000	0.0000	0.0007	0.0006
skewness	-0.2655	0.1800	-1.0229	0.3288	0.3628	-0.9698
kurtosis	5.2288	5.9751	20.2308	8.0668	32.1347	20.8991
ADF	-13.9946***	-15.1899***	-15.4439***	-13.7478***	-11.6121***	-14.0693***

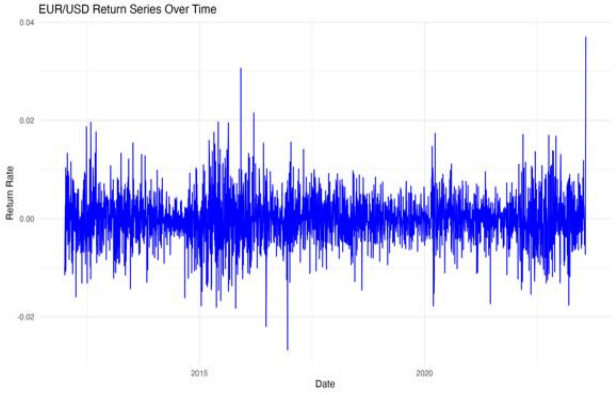
Note: *** denotes that the ADF tests are statistically significant at 1% significance level.

The plots for the continuously compound rates of return for various exchange rates and WTI and Brent crude oil are visualized in Figure 7. Clearly, the plots suggest the series are stationary, as confirmed by the ADF test in Table 1. There are, however, several spikes in WTI and Brent rates of return.

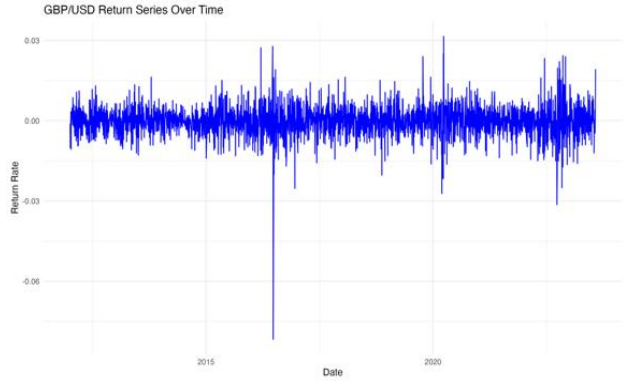
Noticeably, during the beginning of 2020. The COVID-19 pandemic caused unprecedented disruptions to global economic activity, leading to a steep drop in demand for oil as travel restrictions were imposed and industries slowed down. This sudden fall in demand came at time when the world was experiencing an oversupply of crude oil, due to a disagreement between Organization of the Petroleum Exporting Countries (OPEC) and Russia over oil product cuts. The combination of the pandemic's effect (reduction in demand) and the excess supply due to the disagreement caused oil price to plummet. The situation was exacerbated in April when the price of oil even. Eame negative, as the sellers were paying for the buyers to take oil off their hands due to storage limitations.



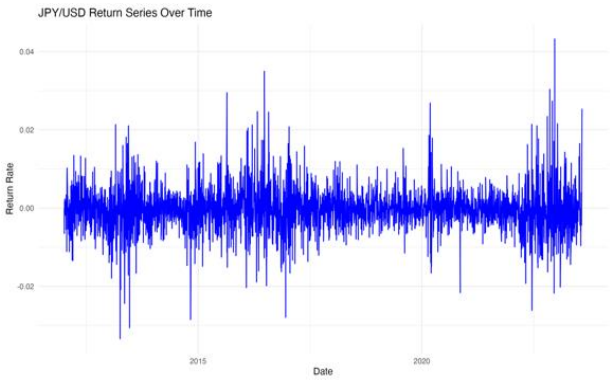
(a) AUD/USD.



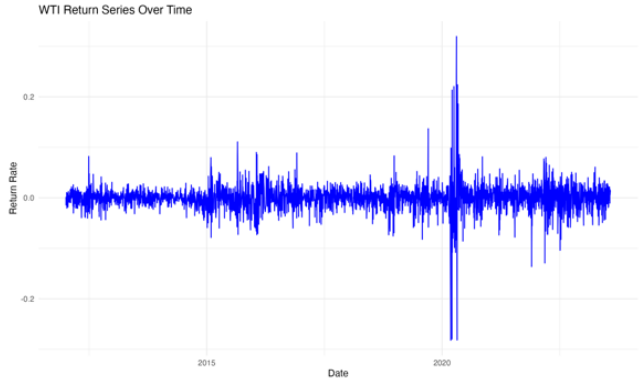
(b) EUR/USD



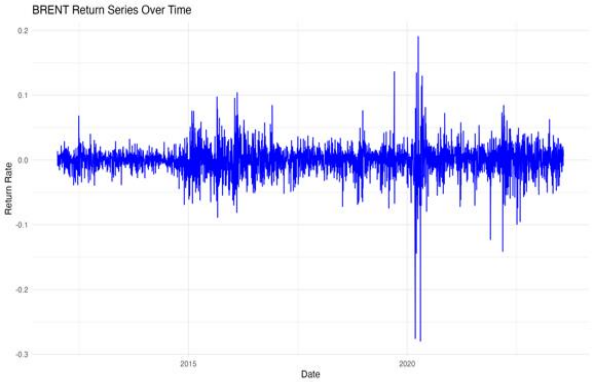
(c) GBP/USD.



(d) JPY/USD



(e) WTI.



(f) Brent.

Fig 3. Plots for continuously compounded rates of return for various exchange rates and WTI and Brent crude oil.

4.2. Method

The VAR model a type of a multivariate time series model that capture linear interdependencies among multivariate time series. The VAR model is designed to analyze the dynamic impact of changes in each variable on itself and on the other variables in the system. Consider y_t as a k-vector of endogenous variables. A VAR (p) model can be represented as:

$$y_t = c + A_1 y_{t-1} + A_2 y_{t-2} + \cdots + A_p y_{t-p} + e_t, \quad (1)$$

Where c is a k-vector of constant, A_1, A_2 ..., A_p are $k \times k$ matrices of coefficients, and e_t is a k-vector of errors. The order p is selected using the Akaike Information Criterion (AIC).

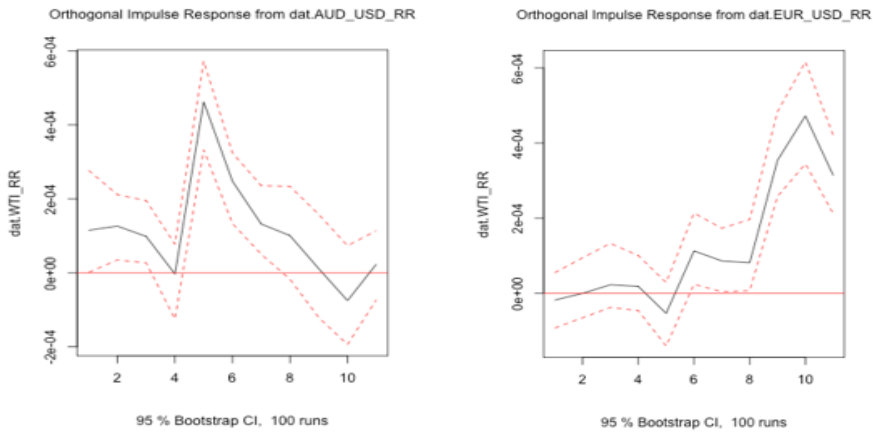
After estimating the VAR system, we then employ the orthogonal impulse response function to analyze the effects of exchange rates on crude oil returns. Note that the impulse response functions trace the impact of one-unit increase in the error term of one of the variables on current and future values of the endogenous variables. However, a challenge arises when the errors in the VAR system are correlated. To address this, we need to use the orthogonal impulse response functions

The rational for using the VAR and the orthogonal impulse response functions in analyzing the rates of return for the exchange rates and crude oil is multifaced. Firstly, VAR models are inherently multivariate, making them ideal for studying the interrelationships between these variables. Secondly, financial and economic time series such as returns for exchange rates and crude oil often exhibit temporal dependence and cross dependence, VAR captures these dependencies very well. Thirdly, the VAR model allows us the examine how shocks to one variable (e.g. EUR/USD exchange rate returns) will influence future values of another variable (e.g. Brent oil rates of return), and vice versa. To summarize, the VAR model combined with the orthogonal impulse response function offers a robust framework for examining the dynamic interactions and responses between exchange rates and crude oil returns.

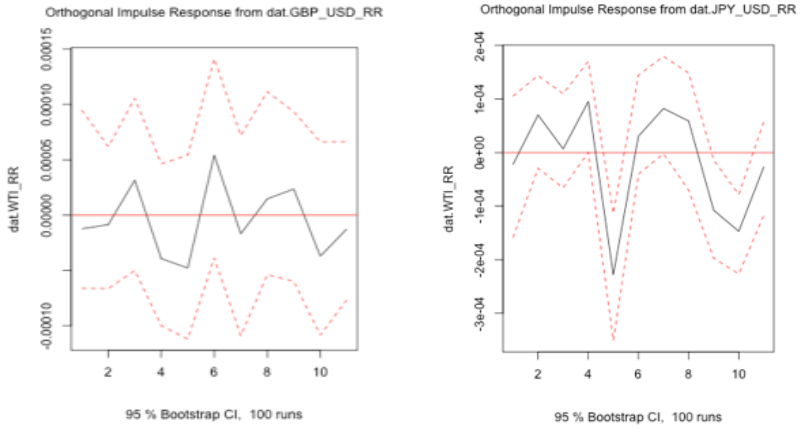
4.3. Results

Through a comparative analysis of the form, amplitude, and length of the impulse response, valuable insights may be obtained into the features and behavior of the system or signal being investigated.

First, we investigate the effect of WIT oil returns to a shock of various exchange rates. Plot (a) visualizes the response of the WTI crude oil returns to the AUD/USD, which shows a sharp initial peak, followed by a decrease over time. The patten is indicative of volatile but diminishing impact over time. Plot (b) characterizes a sustained and increasing trend over time for the response of Brent crude oil returns to the EUR/USD exchange rate shocks. This suggests that the EUR's movement has a prounced and lasting effect on WTI crude oil returns. Plot (c) suggests that there is no significant relationship between the WTI crude oil returns to the USD/GBP exchange rates. Plot (d) suggests that the response of WTI crude oil returns to the JPY/USD exchange rates fluctuates from positive to negative, with the negative responses being statistically significant.



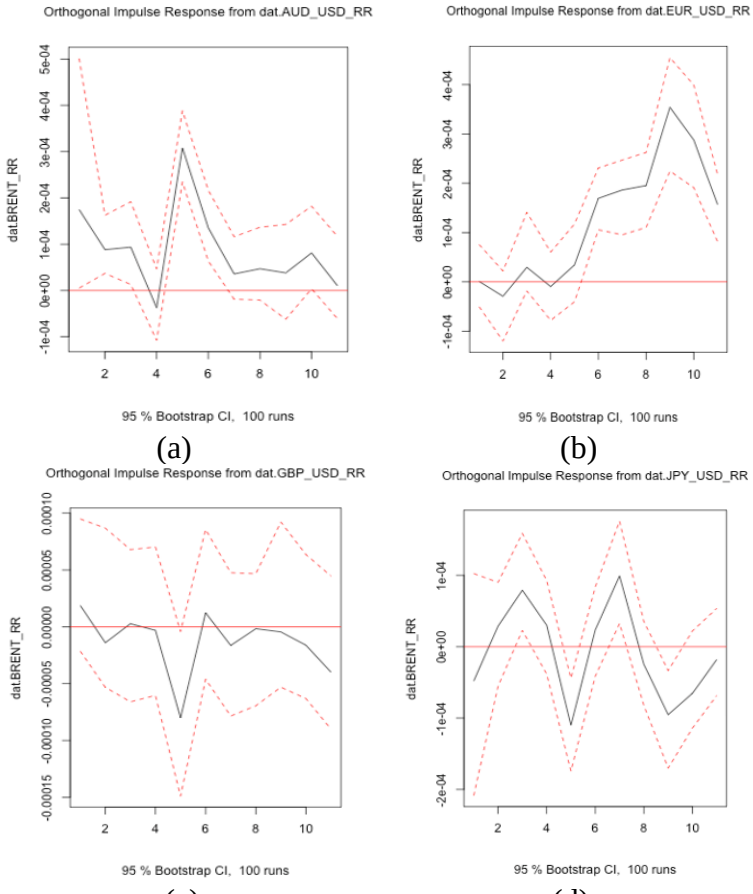
(a) (b)



(c) (d)

Fig 4. Orthogonal Impulse Response of WTI from various exchange rates.

Second, we investigate the effect of Brent oil returns to a shock of various exchange rates. Plot (a) shows the response of Brent oil returns to a shock in the AUD/USD exchange rate. Initially there is a sharp peak at t=5, indicating a strong short-term response, which quickly stabilizes and oscillates within the confidence interval, similar to the WTI. Plot (b) indicates that the response of Brent crude oil returns to shocks in the EUR/USD exchange rate started off with a gradual increase, reaching a peak around the 9th period before declining. Plot (c) finds that the impulse response started below the baseline (0), suggesting an initial negative impact on the Brent crude oil returns following a positive shock in GBP/USD exchange rates. Plot (d) suggests that the response of Brent crude oil returns to the JPY/USD exchange rates fluctuates from positive to negative, suggesting a sustained oscillating effect of the Japanese Yen's appreciation against the USD on Brent oil returns. Note the only different for Brent and WTI is that the positive impulse responses are significant here.



(a) (b)

(c) (d)

Fig. 5 Orthogonal Impulse Response of Brent from various exchange rates.

Also, it is clear that the results from WTI and Brent show similarity, which is consistent with both WTI and Brent as major international crude oil benchmarks.

5. Conclusion and Discussion

The empirical investigation utilizing the VAR model and the orthogonal impulse response functions has offered significant insights into the dynamic interplay between exchange rates and crude oil returns. In particular, through the use of the orthogonal impulse response functions, we have been able to dissect and interpret the complex relationships, identifying the impact of one variable's shock on the future values of others in the system. The analysis reveals that the exchange rates change indeed exert a significant influence on crude oil returns.

The findings underscore the critical role of exchange rates in shaping the crude oil prices. The strong linkages between these markets suggest that investors and policy makers must maintain a keen awareness of foreign exchange movements when making decisions related to crude oil investments or formulating policy. This is particularly important for countries heavily reliant on oil exports or imports.

Furthermore, while the study provides a detailed explanation of the relationships at hand, it also acknowledges the limitation inherent in any econometric analysis. The significant of the impact during certain periods and the lack of statistical significance in others suggest the possibilities of other underlying factors at play, which were not easily quantified and may not be captured by the scope of the current modelling framework.

References

[1] Coudert, V., Couharde, C., & Mignon, V. (2015). On the impact of volatility on the real exchange rate–terms of trade nexus: Revisiting commodity currencies. Journal of International Money and Finance, 58, 110-127.

[2] Yousefi, A., & Wirjanto, T. S. (2004). The empirical role of the exchange rate on the crude-oil price formation. Energy Economics, 26(5), 783-799.

[3] Ghosh, S. (2011). Examining crude oil price-Exchange rate nexus for India during the period of extreme oil price volatility. Applied Energy, 88(5), 1886-1889.

[4] Reboredo, J. C., & Rivera-Castro, M. A. (2013). A wavelet decomposition approach to crude oil price and exchange rate dependence. Economic Modelling, 32, 42-57.

[5] Hartley, P. R., & Medlock III, K. B. (2014). The relationship between crude oil and natural gas prices: The role of the exchange rate. The Energy Journal, 35(2), 25-44.

[6] Atems, B., Kapper, D., & Lam, E. (2015). Do exchange rates respond asymmetrically to shocks in the crude oil market? Energy Economics, 49, 227-238.

[7] Jammazi, R., Lahiani, A., & Nguyen, D. K. (2015). A wavelet-based nonlinear ARDL model for assessing the exchange rate pass-through to crude oil prices. Journal of International Financial Markets, Institutions and Money, 34, 173-187.

[8] BAL, D. P., & Rath, B. N. (2015). Nonlinear causality between crude oil price and exchange rate: A comparative study of China and India. Energy Economics, 51, 149-156.

[9] Yunusa, L. A. (2020). Exchange rate volatility and Nigeria crude oil export market. Scientific African, 9, e00538.

[10] Sun, C., Zhan, Y., Peng, Y., & Cai, W. (2022). Crude oil price and exchange rate: Evidence from the period before and after the launch of China's crude oil futures. Energy Economics, 105, 105707.